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ABSTRACT

In light of recent international studies regarding children's mathematics achievement, this review examines United Kingdom research and literature into early numeracy. The review is designed to provide information about a range of teaching strategies as well as to stimulate discussion and challenge current practices. The review addresses the following topics: (1) (introduction) the growing concern about falling standards in school effectiveness and educational achievement; (2) recent developments and initiatives, including the National Numeracy Project and a recent Government White Paper; (3) Piaget's influence on current approaches to teaching mathematics in the early years; (4) the home as a context for numeracy development; (5) children's knowledge and experience of number before entering school; (6) content and context of teaching and learning; (7) interactive basis of early learning; (8) mental calculation; (9) role of the teacher; (10) links between literacy and numeracy; (11) management roles and responsibilities; (12) role of preschool settings; (13) math schemes and workbooks; and (14) implications for teachers, for partnership with parents, for staff development, and for management. Contains 27 references. (KB)

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Numeracy in the Early Years

What the Research Tells Us

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Numeracy in the Early Years

What the Research Tells Us

Dorothy Caddell

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Foreword	v
1. Introduction	1
2. Recent developments and initiatives	2
3. The influence of Piaget	3
4. The home as a context for numeracy development	4
5. Children's knowledge and experience of number before starting school	5
6. Content and context of teaching and learning	6
7. Interactive basis of early learning	9
8. Mental calculation	10
9. Role of the teacher	11
10. Links between literacy and numeracy	12
11. Management roles and responsibilities	14
12. Role of pre-school settings	15
13. Maths schemes and workbooks	16
14. Implications	18
References	21

In the light of recent international studies into the attainment of children in mathematics, and the current focus on pre-school and the early years of education, Scottish CCC commissioned this review of UK literature and research into early numeracy. The intention was to offer education authorities, schools and others easy access to the key findings of recent research.

The findings themselves will not bring about change or improve attainment in Scottish schools. However, the research provides a secure base on which support materials and staff development can build. It is hoped that this publication will, in addition to providing information and explanation about a range of strategies, stimulate discussion and, perhaps, challenge current practices.

1.1 For some time now there has been growing concern and increasing media coverage about falling standards in school effectiveness and educational achievement. The focus of this report is early numeracy. Comparisons with international numeracy standards have raised concern about the poor attainment of British children and have resulted in the teaching of mathematics being 'put under the microscope'. A library search reveals a number of international articles in this field and, where appropriate, brief reference is made to some of these. While it is clear that a wider review would be of value, this report is largely confined to some of the UK literature and research about early numeracy published within the last four or five years. Key issues emerging from these have been identified and the report is organised around these.

1.2 Merttens (1996:17) suggests that mathematics in a state of flux provides opportunities 'to reflect upon some of the "taken for granted" ideas and practices of the last ten or twenty years in primary education'.
Although the research into early numeracy is not as prolific as research into reading and writing, there is evidence of a growing body of research which is questioning current teaching approaches and strategies, and emphasising the need to reassess these.
Piaget's influence on current practice is acknowledged but the narrow focus of the Piagetian approach which underpins early number work is now being challenged. A focus on children as 'powerful mathematical thinkers' and the crucial role the teacher plays in the development of early numeracy experiences, by interacting, communicating and instructing, signifies a marked shift away from Piaget's earlier ideas.

1.3 In the literature, links between literacy and numeracy are explored. Concern about levels of early literacy achievement has resulted in a number of comprehensive schemes being developed. Evaluation of early intervention projects is providing valuable insights into which aspects or strategies are effective and there is evidence of studies exploring whether methods used in developing literacy and writing could be adapted for use with numeracy.

1.4 The powerful influence that the home, family and community have on a child's attitude and educational achievement is now widely acknowledged and research findings highlight the extensive, informal mathematical knowledge, concepts and strategies that children gain from participating in everyday routines and social interactions. There is emphasis on the need to be aware not only of the diversity of experiences and understanding that children bring to school, but also of the importance of taking account of this informal maths when planning and implementing maths programmes for the early years.

2.1 In 1996 the **National Numeracy Project** was set up in England and Wales to improve standards of numeracy and offer enhanced teacher training and support. This project, which is intended to run for five years, identifies factors associated with raising numeracy standards at school management and classroom level. The objective is to offer a detailed framework of learning objectives, creating a balance between whole class and group teaching and between direct, instructional teaching and interactive oral work and mental calculation.

2.2 The recent **Government White Paper** as reported in the *Guardian* (Tuesday 8 July 1997) indicates the government's intention to introduce a number of measures to raise levels of numeracy. Prescribed times are given for literacy and numeracy teaching and the emphasis is on individual schools meeting challenging targets set for them. A feature of the White Paper is the notion that local authorities, parents and teachers all have a part to play in the raising of literacy and numeracy standards. The roles and responsibilities of these different parties are set out.

2.3 A number of initiatives have been developed which have extended parental involvement in areas of the curriculum, particularly in reading. The PACT (parents, children and teachers) initiative developed in the 1980s encouraged parents to hear their children read at home. The effect of initiatives such as this was to give parents a more direct role in their children's learning and to highlight the potential of home-based initiatives in other areas of the curriculum. IMPACT (started 1986) is an ongoing initiative, originally modelled on PACT, set up to encourage parents and children to share maths activities in the home setting. The project has now extended beyond the UK to Europe, the USA and Canada. It illustrates how homework tasks can be adapted to offer opportunities for parents to support their children's learning. The findings of the project suggest that this is an effective way of raising children's achievement and narrows the gap of social disadvantage.

2.4 Parent Prompts is an initiative developed in Strathclyde Region to inform parents of approaches taken in school and to form the basis of activities which they could undertake with their child in the home setting. The prompts are all tied to specific aspects of 5–14 guidelines and provide an opening for parent and child to share some aspects of the child's learning.

2.5 There is evidence of an increasing number of Regional Authority documents being produced which focus specifically on raising achievement in numeracy. For example, Birmingham City Council designated 1997 as its 'Year of Numeracy' and produced booklets for teachers describing existing strategies and initiatives. This offered opportunities to share and disseminate information about characteristics of successful interventions in teaching and learning of numeracy. Many other examples of significant initiatives can be found. In the context of this report these could not be fully explored. The final section of the report does, however, stress the need to consider these carefully if future planning and policies are to be effective.

2.6 An initiative 'Counting on Success' has been developed in Northern Ireland. At the time of this report no details were available but it is important that this initiative be further explored.

3.1 Current maths schemes and approaches to teaching maths in the early years continue to be strongly influenced by Piagetian views of numeracy.

3.2 Wright (1992) highlights the significant influence that Piagetian theory has on early childhood mathematics curricula in Australia. Although Piaget's ideas continue to dominate thinking about pre-number and early number, the recent trend to a counting base approach has resulted in Piaget's ideas having less influence in the topic of introducing operations. It is important to explore further published articles which address the dominant influence of Piaget.

3.3 There is a strong message in the literature over the last few years that the influence of Piaget needs to be reassessed. Recent research, which not only re-examines but increasingly challenges Piaget's approach, marks a very significant change in educational thinking about numeracy at home and in school.

3.4 The Piagetian notion that children must grasp the principle of conversation of quantity before they can develop the concept of number is, in the light of recent research, viewed as too narrow.

3.5 Evidence from the research into children's knowledge and experience of number before starting school highlights the limiting effect of Piagetian views about the conservation of number on approaches to number.

3.6 The appropriateness of the existing maths curriculum is questioned, in view of the emphasis placed on the importance of children gaining substantial experience of various pre-number tasks before tackling the more complex idea of number.

3.7 Recent research findings suggest that children who fail a Piagetian task should not be denied number work, since they could well have a concept of number which is adequate for many basic numerical situations and which could provide a sufficient basis on which to build.

3.8 Piaget's view that mathematical concepts occur spontaneously and are essentially constructed by the children themselves implies a non-interventionalist role for the teacher. Recent research evidences the crucial role of the teacher in enhancing mathematical knowledge and understanding.

Details of 'recent research' sources can be found in the sections that follow.

Much of children's learning before they go to school is embedded in the network of people and their purpose and interest that make up the community.

Hughes (1986)

4.1 The home and community are now recognised as important contexts of children's early cognitive development. Recent research shows that, before starting school, children build up a considerable amount of mathematical knowledge through experiences and interactions in familiar everyday routines. Further exploration of the opportunities offered and learning processes involved is needed.

4.2 A study by Munn and Schaffer (1993) describes the frequency and variety of experiences related to emergent literacy and numeracy, and investigates the contexts in which they occur. Findings suggest contrasts in the ways that the home and pre-school settings support early numeracy development. The home setting, where parents and children are likely to play games with numbers, offered more opportunities than nurseries where there was a relative scarcity of numeracy experiences compared with literacy experiences.

5.1 Recent research underlines the importance of the early learning that takes place within the home environment in providing a framework upon which future learning will be built in school. The challenge that this presents to schools is acknowledged in the literature and has fuelled further research assessing the knowledge and ability that children bring to school.

5.2 A study by Munn and Schaffer (1993) investigated the mathematical knowledge that children in a small reception class had before starting school. It found that children build up a considerable amount of mathematical knowledge through experiences and interactions in familiar everyday routines which form the context of children's early cognitive development.

5.3 Children were tested in a variety of activities including knowledge of counting words, counting objects up to 10, order variance, reading numbers, writing numbers, ordering numbers (what comes before, after), understanding number operations of + and −, division as sharing, estimation, algebra. Findings highlight that children were already displaying competencies and knowledge of concepts which the school planned to teach in the first year of school.

5.4 The extent to which children may demonstrate early competencies is further shown by Carruther's (1997) observations of the considerable range and depth of knowledge that her child gained in the home setting prior to school. Although this is a very limited study, focused on one child, it does serve to highlight the diversity of experiences and opportunities that different family environments may offer.

5.5 A study by Aubrey (1997) looked at the extent to which teachers took account of children's existing mathematical knowledge and understanding. It found that:

- children's teachers were unaware of existing mathematical experiences at school entry
- existing knowledge and understanding was not used to inform teaching decisions.

The idea that children's prior numerical knowledge and general cognitive abilities are underestimated, especially in the first year at school, suggests there is a need for teachers to access children's prior knowledge and ongoing cognitive processing in order to carry out instruction.

5.6 These findings may have further implications for the traditional class approach to the teaching of maths in the early years. This is explored in 'Content and context of teaching and learning'.

5.7 Wright (1992) summarises some recent Australian and New Zealand research in early mathematics. Findings are consistent with the idea that the curriculum is not well matched to the prior knowledge and skills that children possess.

6.1 Current research findings raise issues which emphasise the need to re-evaluate the structure and content of the early years mathematics curriculum and in particular to give more consideration to the provision of specific strategies and techniques.

6.2 Threlfall (1996) reviews arguments for the value of practical number apparatus and examines the activities for which this is used. Three strands in learning arithmetic are identified in which practical number apparatus has a role to play: understanding its meaning; gaining familiarity; and learning how to get answers efficiently in a range of ways, including paper and pencil methods. Threlfall asserts that if the true value of practical number apparatus as 'a means for guided discovery and an aid to instruction' is to be realised then a change of emphasis in its use must be considered. He suggests that purposes must be clearly linked to activities so that teachers can use apparatus appropriately, taking into account children's existing knowledge and skills.

6.3 Threlfall stresses the importance of knowing the limits of the use of practical materials. Practical material can be used for 'demonstrating the characteristics and meaning of the algorithm' but the use of practical number apparatus to help with calculations, he argues, is a misuse of the apparatus. The value of materials 'is in how imagery and insights gained from them help in keeping the child in control, providing a safety net when automaticity breaks down'. He concludes that although practical materials have a role to play in activities which aid subsequent calculation they should not be used to 'get the answer'.

6.4 Wright (1992) provides 'a historically and theoretically based critique of the topic of number learning in early childhood mathematics' and concludes that there is an urgent need to review current practice to bring curricula into line with research findings.

6.5 He summarises relevant Australian research which highlights the important role of counting in children's numerical development. Findings show not only that counting is a central activity used in problematic situations but also that 'the activity of counting provided an experiential basis for the development of number concepts'. Recommendations arising from this work are that:

- work with the standard pencil and paper algorithms should be abandoned and replaced with work on the schemes of counting on, counting up to and counting down to
- children should not be drilled on their basic addition and subtraction facts while they are in the stage of sequential integration operations.

(Steffe and Cobb 1989:321)

Implications of these recommendations for published texts and schemes are noted in Section 13 of this report.

6.6 Further questions about aspects of the early years programme are raised by research cited in Wright's article. For example, Hunting's (1989) assertion that 'Sharing is ideal for stimulating counting ...(and) fundamental mechanisms for learning whole numbers and fractions appear to develop side by side' challenges

the generally held belief that fractions should not be introduced until around eight years of age or even later.

6.7 Reference is made to US classroom-based interventionist research that has taken place in the last five years (Cobb, Wood and Yackel, in press). The main aim of this is the application of constructivism to classroom settings. Issues of current interest are:

- children's construction of increasingly abstract arithmetical objects
- children's moral and emotional development
- the teacher's learning in the classroom
- the changing nature of children's beliefs about the activity of doing mathematics, their role as students, and the teacher's role.

6.8 The suggestion that this US research programme could provide a rich model for constructivist research in Australian classrooms, and a viable basis for the reconstruction of current practice in the early years, highlights the significance of the study of maths learning and teaching from a constructivist perspective in dealing with the questions being raised about early childhood mathematics. The results of constructivist research suggest the need for:

- high priority to be given to classroom intervention studies
- this research to be extended to more advanced mathematics topics
- investigations to take place in 'real classrooms'.

6.9 Recurring and related themes of recent research in terms of content and context constitute a strong argument for:

- critically reviewing the curriculum for the approach to number in the early years
- a central focus on problem solving with children engaging in a wide range of activities

6.10 Recent studies into the extent of pre-school children's mathematical understanding and knowledge suggest that children enter school with both considerable experience and competence in sorting and matching. This calls into question the appropriateness of such activities as an initial focus of an early years maths programme in school.

6.11 Research findings indicate that teachers underestimate the rational powers of young children.

6.12 Aubrey (1993) shows that, even without formal experience of sorting, children show a high level of understanding of number and this raises questions about whether the concepts of sets, mapping and relations, although important, are necessary prerequisites for an understanding of number (Thompson 1994).

Research findings show that:

- young children make extensive use of counting skills when solving problems involving mental arithmetic calculations, particularly in situations relevant to them
- there are links between understanding of number concepts and meaningful counting.

This suggests that counting strategies have an important part to play in the development of children's number understanding and that there is a need to concentrate more on the development of rational counting skills.

6.13 There is general agreement in the reviewed literature of a need to think more about the formal aspects of numeracy and to develop to a greater extent instructional practice which emphasises conceptual development and cognitive change.

6.14 Specific conclusions drawn from an investigation into the mathematical knowledge and competencies that children bring to school (Aubrey 1993) highlight the need to provide activities and develop strategies which:

- embed maths in familiar and authentic activities
- build on the range of strategies that children themselves generate to encourage them to extend these in a way which does not undermine their natural inventiveness
- enable children to link informal knowledge and strategies to more conventional procedures
- offer a gradual move through different stages of mathematical representation from personal to more formal in real, everyday problem solving situations
- allow the child's existing forms of representation, problem solving and knowledge to be supported and extended.

6.15 An important issue identified is the assumption that teachers are aware of the mathematical knowledge that children bring to school. In the second phase of her research Aubrey (1994) investigated:

- the knowledge and beliefs that teachers hold about learning and teaching mathematics, about young learners and about maths as a subject
- the extent to which informal maths knowledge that children possess is taken into account when planning instruction.

6.16 Aubrey's findings from interviews with teachers show that:

- pre-school profiles are not used when planning
- topics are chosen by teachers
- practice was seen to be 'based on rational analysis of subject content rather than empirical analyses of children's knowledge and strategies under problem solving conditions'.

6.17 These findings present a huge challenge in terms of making teachers more aware of the prior mathematical understanding and knowledge that children have, the means of accessing this, and an appreciation both of children's misapprehensions, and of the stages of learning they pass through in gaining mastery of subject matter.

6.18 Although Aubrey's study was carried out in a pre-school setting there are obvious ramifications for teaching at all stages of the primary school.

Talk is a natural, effective and crucial strategy.

(Menmuir and Adams 1997)

7.1 Recent research locates children's cognitive development and learning very firmly within a social and interactive framework. This emphasises the need for teachers to develop a responsive style of interaction. The evidence of research suggests that the importance of adult–child, child–child and parent–child interactions cannot be underestimated.

7.2 The need to look beyond how individuals construct meaning from mathematical activities and to give more attention to the interpersonal or social aspects of mathematical learning and teaching is highlighted by US research cited in Wright (1992:137):

We will be unable to talk about the specifics of instruction in a theoretically grounded way unless we place the analyses of learning within the context of social interaction.

(Cobb, Wood and Yackel, in press)

7.3 A study by Munn and Schaffer (1993), to gauge the quality of experiences of 2 and 3 year old children attending Scottish local authority nurseries in terms of the type of adult–child interaction in which they were embedded, stresses the importance of the interactive basis of early learning in both literacy and numeracy.

7.4 Findings highlight the importance of adult encouragement and responsiveness in children's numeracy, and identify an association between organisational systems which assign children to particular adults and enhanced literacy or numeracy experiences.

7.5 Munn and Schaffer suggest that the implications of the findings for adult–child interactions are that:

- one-to-one adult–child interactions should be maximised
- a system which assigns children to particular adults should be introduced.

8.1 Current research evidences growing recognition of the importance of mental algorithms and mental computation in helping children to understand and use them effectively. The need for an increased focus on developing mental skills is strongly emphasised.

8.2 Bierhoff (1996) shows, through a comparison of mathematical written texts, the greater emphasis that continental countries put on mental arithmetic to promote conceptualisation of number and 'extended chains of reasoning'.

8.3 A number of suggestions for encouraging mental skills are made:

- less reliance on concrete and visual materials which inhibit the development of mental calculation, and more support for developing optimal mental calculation strategies
- more emphasis on horizontal as opposed to vertical addition and subtraction methods, as a means of developing mental methods
- more emphasis on teaching two digits as single concepts and less on 'dissecting' numbers according to place value
- verbal interaction between teacher and pupil and between pupil and pupil where there is an increased focus on developing mental skill.

8.4 The National Numeracy Project referred to earlier in this report has put an emphasis on mental calculation and prescribes 10 minutes for oral and mental work within each lesson.

Children's numeracy is fundamentally affected by what the teacher provides and how the teacher behaves.

Merttens (1996)

9.1 This statement highlights current thinking about the crucial role the teacher plays in developing children's numeracy skills.

9.2 Research findings increasingly emphasise the need for teachers to reassess the role they play, to think more about the formal aspects of teaching (Merttens 1996), consider the role of explicit teaching (Hughes 1986) and offer more direct teaching of more advanced concepts (Aubrey 1993).

9.3 Threlfall (1996) underlines the importance of the teacher adopting an active guiding role, 'appropriately intentioned in her interactions', if the great potential of practical number materials to contribute to meaning in arithmetic is to be used.

9.4 Menmuir and Adams (1997) have produced a framework to help teachers develop in young children investigative methods of working in mathematics in which the crucial and complex role of the adult in managing both the learner and the learning is underlined. The framework is:

- start from the child's persistent concerns
- link these to intentions for learning supplied by the adult
- listen to and observe children
- focus the challenge into mathematical inquiry
- take control of getting started
- support children in formulation, implementation and planning
- help children realise
- keep children going on the implementation of the revised plan
- check and modify to maintain original 'fair' opportunities.

9.5 Menmuir and Adams' experience with staff suggests that inquiry learning in maths is most effective when teachers have a good understanding of what mathematics really is.

9.6 The extent to which teachers' mathematical knowledge and understanding contributes to the opportunities that they provide for their children to learn mathematics is the focus of a study by Aubrey (1997) assessing the pedagogical knowledge of four experienced teachers.

9.7 In Aubrey's study, the content and process of individual lessons and series of lessons over a child's first year at school were recorded and the extent to which teachers took children's existing ideas into account was noted.
Findings highlight:

- the important influence of the teacher's knowledge of subject content, and the competence of pupils, on classroom practice (teacher's pedagogical subject knowledge, it is stressed, is fundamental to effective practice)
- the need to recognise the links between the formal knowledge of the school curriculum and informal practical knowledge.

10.1 For some time now, widespread concern about standards of literacy has resulted in a number of research projects to identify elements of practice which support and encourage literacy development.

10.2 In the US report *Everybody Counts* (1989), reference is made to 'verbal' and 'mathematical' literacy. The inter-relatedness of these two types of literacy is highlighted:

> *Without the ability to read and understand, no one can become mathematically literate. Increasingly the reverse is also true: without the ability to understand basic mathematical ideas, one cannot fully comprehend modern writing such as that which appears in the daily newspapers.*

10.3 A brief examination of the titles of current articles indicates a number of studies which explore whether elements which characterised literacy programmes can be adapted for use with numeracy.

10.4 Merttens (1996) notes that attempts to build literacy tasks around what the child already knows and can do have been further articulated through the 'developmental writing' approach, and explores the appropriateness of this for numeracy.

Suggestions for classroom practice are identified.

- Seek out situations where a mark is a solution to a problem.
- Use role play to build children's confidence in using mathematical marks. (The use of role play it is suggested (Evans 1992) can also be an innovative teaching method to address the problem of 'buggy algorithms' – the term used to describe systematic errors.)
- Seek out opportunities to engage in mathematical recording.
- Provide writing apparatus alongside practical mathematical tasks.
- Invite children to 'put something down on paper' to show others what they have done.

10.5 Merttens (1997) suggests that encouraging children to engage in mathematical recording might help them to bridge the gap between a practical activity, mathematical thinking and symbolic reading. He asserts, however, that children should be encouraged to record their sums only if they are allowed to write in their own mathematical way.

10.6 Further implications for maths teaching, if an adapted literacy approach is to be considered, are suggested by Stoessiger and Wilkinson (1991) whose research took place in schools currently implementing strategies for emergent writing.

- Children have to be immersed in a mathematically rich environment as they are for emergent literacy.
- Mathematical work within this environment has to be adapted to minimise 'failure' as an outcome.
- The use of open-ended questions helps to reassure that no one correct answer is being sought.

10.7 Findings were not limited to the early years. Teachers in the upper stages of the primary school also reported that, if conventional mathematics were

presented in open-ended ways, and children themselves were allowed to make decisions about the numbers they use and the direction they take, mathematical thinking emerges.

10.8 The research highlights an important difference between the way children's existing thinking is challenged in the literacy approach and the way it is challenged in the numeracy approach. Whereas in language children are introduced to more sophisticated language than we expect them to use, in maths we show children only the maths that we assume they are capable of coping with.

10.9 The language model suggests that this is too limiting an approach and that teachers should demonstrate to pupils more advanced maths that they will encounter in the future.

10.10 Munn's (1994) study presents data on the knowledge and beliefs that children in eight Scottish pre-school settings hold about reading and number. The results of this research reflect recent debates about early numeracy and are therefore outlined below.

- A strong link is suggested between children's use of counting and their understanding of numerals.
- The functional use of symbols – an essential literate strategy – is seen to be related to children's use of counting as a strategy.
- Strategies employed by children suggest that young children commonly confuse the notion of 'counting' with 'reading numerals'; this has implications for how young children are introduced to early numeracy experiences.
- Clear links were seen between verbal counting procedures and children's use of the numerical system.
- Iconic numerals were seen to be a transitional strategy to conventionally written numerals.

10.11 Differences in perceived shared purpose of adults and children with regard to literacy and numeracy activities are identified as a possible cause of difficulties in early numeracy.

10.12 Study suggests that, although children's counting may not have the same function as that of adults and other children, it may perform functions which are highly relevant to the children's developing use of the number system.

10.13 It is suggested that there is a need for:

- more structuring of counting activities so that children can see counting as a purposeful activity and the adult meaning of counting can become explicit
- a 'whole child approach' (as opposed to component abilities) to literacy and numeracy
- literate strategies for dealing with quantity.

10.14 In their Australian study focusing on reading printed text, Chapman and Lee (1990) establish that 'texts contain mathematical as well as verbal representations and that mathematical meanings can be made from verbal language'. This, they suggest, highlights the need to acknowledge the role of literacy in the communication of mathematical ideas and to address the consequences for literacy pedagogy.

11.1 The prime focus of the research reviewed has been teaching and learning at classroom level and the quality of this is recognised as being a crucial factor in raising standards. The role and responsibilities of the management team in school is referred to less often in research.

11.2 One study reviewed does, however, highlight the direct educational relevance of the organisational quality of early years settings. Munn and Schaffer (1993) examined variations in nurseries with regard to the frequency of relevant early literacy and numeracy experiences. Their findings suggest that an infant-friendly management style (organising in small groups and ensuring continuity of relationships) is associated with enhanced literacy and numeracy experiences.

11.3 The practical implication, they suggest, for pre-school management is that special attention be given to early numeracy experiences with due regard paid to staff understanding of the role of language and social interaction in the earliest development of quantitative understanding.

11.4 The National Numeracy Project stresses the important role of senior staff in initiating and maintaining necessary changes if, as intended, 'changes that become an automatic part of the school's way of working' are to be brought about. Factors associated with raising numeracy standards at both school management and classroom level are identified.

12.1 The extent of children's development in early numeracy and literacy is described in a study by Munn (1995) in which she observed changes in behaviour prior to school. Findings suggest developing the use of counting as a strategy and recognition of numerals and letters.

12.2 Munn's study highlights a number of important aspects about early development of numeracy and literacy which will have implications for the activities provided in pre-school learning environments. These are:

- number naming develops before letter naming
- acquisition of 1–9 number symbol names was usually quickly followed by the ability to produce the sound of one or two letters
- progress in children's understanding of literacy and numeracy suggests children's understanding of symbols, as communicative systems is an important development taking place
- progress made by children in the first year at school is strongly related to an understanding of symbols which they bring to school with them
- analysis of achievements showed associations between abilities in areas of reading and number 'suggesting that a general symbolic function underpins children's understanding in both reading and number'.

12.3 The pre-school setting is identified as the context in which children are introduced to the adult's meanings of reading and writing. If, as suggested by Munn (1994), children's understanding of the role and importance of reading and counting may be the strongest predictor of school progress then organised pre-school settings have a crucial role to play.

12.4 Observations of children confirmed relations between levels of social organisation of settings and children's literacy and numeracy experiences.

12.5 Munn's (1995) investigation into staff interactions and conversations suggests that adult thought about learning is of prime importance in the construction of learning environments and emphasises that communication between staff plays an important role in the construction of beliefs about children's learning.

12.6 Detailed observations of staff discussions give important insights into how organisations can either constrain or develop adult understanding of children's learning. Findings suggest two factors as important in achieving active involvement from non-teaching staff:

- the way in which the teacher manages her authority
- positive feedback provided by children responsive to educational experiences.

12.7 It is suggested that an appropriate pre-school curriculum can help a child's transition into school by 'ensuring the smallest possible gap between number and written maths'.

12.8 An 'appropriate curriculum', Munn (1994) confirms, is in line with the traditional early years approaches to reading and counting, that is:

- provision which emphasises open-ended concrete activities from which children construct their own meanings for literate and numerate activities rather than overly directed activities in which the adult meaning is imposed on children.

13.1 The reliance of teachers on published material to guide practice in terms of 'checking' children's understanding or to learn about subject content is noted by Aubrey (1997).

13.2 Attention is drawn to the problem of the emphasis on procedural knowledge and calculation skills at the expense of central concepts and ideas, which are often underdeveloped in written texts. The need to re-examine the content of published textbooks is stressed.

13.3 The importance of the quality of written learning material in Britain's widespread 'individualised' approach to the learning of maths is noted by Bierhoff (1996) in his paper comparing primary school textbooks in Britain, Germany and Switzerland.

13.4 Discussions with teachers in Britain led Bierhoff to conclude that their choice of exercises and activities is based on whether they are considered to be 'stimulating' and 'fun'. Bierhoff maintains that, in the eyes of Swiss educationalists, the most important factor responsible for poor attainment in Britain is the failure of British teachers to give prime consideration to whether the exercises and activities in written texts are adequate in enabling children to gain a thorough understanding of mathematical concepts and mastery of mathematical skills.

13.5 Continental countries of Europe (who are higher in the Global Maths League than Britain) put more emphasis on how to teach, not what to teach. They look for the following features in textbooks:

- more time spent on practice and consolidation
- more thorough grasp of number facts 20–100 with more overview exercises on the full range of those numbers
- more distinct progression in the development of advanced concepts and evidence of thorough consolidation of new concepts
- more emphasis on teaching two-digit numbers as single concepts and less on 'dissecting' numbers according to place value
- more support for developing optimal mental calculation strategies with less reliance on concrete and visual materials
- a delay in the introduction of pocket calculators
- more continuous time on topics, in increasing depth and complexity, before moving on
- priority given to mental calculations to promote conceptualisation of number and 'extended chains of reasoning'.

13.6 The importance of verbal interaction is highlighted by a greater emphasis on discussion which enables children to 'see beyond their own methods' and in which the teacher's role is to guide children towards alternative strategies.

13.7 In his article exploring the contribution that practical apparatus can make to the teaching of arithmetic, Threlfall (1996) notes the influence of current published schemes and teacher's guides on the use made of practical number apparatus.

- The use of practical apparatus in pupils' books seems to be predominantly as an aid to calculation which, he suggests, may inhibit rather than enhance a child's ability to bring meaning into arithmetic.

- Teacher's guides offer examples of recommended activities in which to use concrete materials but rarely discriminate these in terms of different purposes. This absence of appropriate guidance to ensure that teachers understand precisely what the activity is for, it is asserted, may be a contributing factor to the ineffective use of practical apparatus.

13.8 Wright (1992) raises a concern that although, in Australia, there is currently a re-emphasis on developing children's understanding through a progressive development of meaning and a corresponding de-emphasis on practice with written procedures and rote memorisation, nevertheless textbooks and the most recently developed State syllabus continue to be shaped by the 1970s' back to basics movement in the US.

13.9 Wright outlines some predominant features which seem to be at variance with current thought and emphasis:

- strong advocacy of the use of structured materials which may emphasise skill development rather than developing meaning in problem solving contexts
- textbook exercises with pictorial representation of addition which may interfere with 'counting on' strategies.
- textbook tasks which limit children to developing and practising localised, rule bound procedures to find the right answer and which do not help develop number sense or more advanced strategies
- a lack of emphasis on activities which develop counting procedures
- early introduction of written columnar forms of multi-digit addition and subtraction which concentrate on rote rules and do not provide adequate support for constructing mult-unit conceptual structures (Fuson 1990:274).

Implications for teachers

- Teaching numeracy is a complex task. There is no simple solution to underachievement.
- The important role of counting to provide an experiential basis for the development of number is underlined.
- There is a need to focus on the development of more rational counting skills.
- There is general agreement on a need to think more about formal aspects of numeracy.
- The need for an increased focus on developing mental skills is strongly emphasised.
- There is a need to examine closely the use of calculators in the early years.
- The use and content of written texts needs to be carefully considered.
- There is a need to provide activities which embed maths in familiar and authentic activities.
- Activities should build on the range of strategies that children themselves generate.
- A strong link is suggested between children's use of counting and their understanding of numerals.
- The functional use of symbols – an essential literate strategy – is seen to be related to children's use of counting as a strategy.
- Clear links are seen between verbal counting procedures and children's use of the numerical system.
- Iconic numerals are seen to be a transitional strategy to the conventionally written numerals.
- It is widely acknowledged that children's cognitive development and learning is located very firmly within a social and interactive framework.
- Numeracy is not confined to activities that occur in the classroom context.

Implications for partnership with parents

- The crucial role of parents in the children's learning is widely acknowledged, and the home and community are recognised as being important contexts for early numeracy experiences.
- There is a need to develop parental involvement further and encourage parental participation in early numeracy activities.
- When developing strategies to encourage parent participation, both home based and school based activities need to be carefully considered.
- The focus of homework as 'an essential part of a good education' (Department for Education and Employment 1997:58) further highlights the need for consultation and effective communication with parents.
- Parents and non-teacher trained staff involved in 'paired' and group activities will need support and information about how to be responsive to the cues children provide.

Implications for staff development

- There is a need to consider 'taken for granted' practices both in terms of content and context, in particular to give more consideration to the provision of specific strategies and techniques.
- The influence of Piaget needs to be reassessed.
- There are strong arguments for critically reviewing the approach to number in the early years curriculum.

- Strategies employed by children suggesting that young children commonly confuse the notion of 'counting' with 'reading numerals' have implications for how young children are introduced to early numeracy experiences.
- There is an important challenge ahead if this re-emphasis and re-evaluation of early numeracy is to be translated into effective classroom practice.
- The teacher's role is crucial in enhancing mathematical knowledge. The crucial and complex role of the adult in managing both the learner and the learning is underlined.
- The need for teachers to reassess the role they play is emphasised.
- The quality of teaching and teachers' pedagogical subject knowledge is fundamental to effective practice.
- Staff development programmes need to be initiated to enhance teachers' knowledge and understanding of how numeracy develops.
- There are important implications for staff development in terms of how best to prepare teachers for working in partnership with parents.
- The implications for staff development programmes raised by Munn's (1994) findings of 'considerable reluctance amongst non-teacher trained pre-school staff to deal with issues concerning literacy and numeracy' need to be carefully considered.
- Differences in pre-school experience have a significant impact on children's early numeracy and yet children's prior numerical knowledge and cognitive abilities are being underestimated.
- There needs to be more understanding of opportunities offered and learning processes involved in everyday routines and social interactions.
- Ways of assessing children's prior knowledge need to be explored.
- Teachers need to feel confident that they can meet the challenge that the interaction between the process and assessment of prior knowledge and instruction presents.
- There is a need to consider practical organisation of activities to enhance child-child discussion and interaction.
- Links between literacy and numeracy are identified. The potential for learning from strategies to improve literacy achievement needs to be fully explored.
- There is a need for pre-school settings to offer activities to promote early numeracy skills to the same extent as early literacy skills.

Implications for management

- Particular attention should be paid to the approach to the teaching of numeracy adopted by the National Numeracy Project and to the ongoing monitoring and evaluation of this.
- The wide range of initiatives that have been developed at Regional Authority level aiming to improve numeracy standards need to be fully explored and documented.
- A directory of current projects being implemented to raise standards of achievement in numeracy could be compiled to open up channels of communication between these and help identify characteristics of successful strategies in the teaching and learning of numeracy.
- Raising numeracy standards is a global concern and issues relating to numeracy are now being discussed internationally. It is important that there is ongoing monitoring of current international trends.
- The use of concrete and visual resources needs to be reviewed and the arguments for the value of these carefully examined.

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- Reference should be made to strategies suggested in the National Numeracy Project.
- If teacher morale and motivation are to be boosted during this time of change, it is important to work collaboratively with teachers and not merely to 'research' them.
- The reliance of teachers on published material to guide practice in terms of 'checking' children's understanding or to learn about subject content is noted.
- Textbook activities and approaches need to be critically reviewed to ensure that they mirror approaches and strategies based on research evidence.
- A framework of numeracy skills that develop before school may be of value.
- Effective ways of sharing observations and assessment in the transitions between home, pre-school settings and school needs to be examined.
- Children's existing knowledge should be used to inform the teaching of number.
- Consideration must be given to resources, class size and organisation if one-to-one adult–child interactions are to be maximised.

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